Cleaner production practices towards circular economy implementation at the micro-level: an empirical investigation of a home appliance manufacturer

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Abstract

The concept of circularity has been widely discussed in the literature, but the implementation of the circular economy (CE) concept at the micro-level remains unexplored. Manufacturing companies should develop new business strategies and implement new practices in the transition process towards a circular economy model at the bottom-up. Cleaner production (CP) principles and practices have been discussed as essential for CE adoption at the micro-level, but specific studies should be conducted regarding the adoption and effects of cleaner production in promoting CE. Thus, this paper aims to explore the cleaner production principles and practices adopted by a manufacturing company located in an emerging economy in order to understand how those were valuable to foster CE implementation. A case-based research was adopted in this investigation. The CP practices introduced by the company were analyzed, their connections with the requirements to be measured when transitioning to a CE paradigm, and with CE areas at the micro-level. An inductive approach was adopted to develop some propositions regarding CP and CE interactions. The main findings revealed that CP practices for product optimization are valuable to CE implementation regarding circular product design strategies. The CP principle of input substitution is valuable to reduce input and use of natural resources as well as to increase the share of renewable and recyclable resources. Technological optimization can contribute to reducing emissions level. In addition, it could be noticed that CP practices at the production area enable CE practices implementation at the micro-level and a connection with other CE areas (i.e. waste management, consumption, and support). Moreover, the findings confirmed that all CP practices and principles implemented by the company were enablers to the CE issues implementation regarding the new business strategy. Further studies may focus on testing the propositions developed in this study in other manufacturing contexts as well as on the investigation of possible cause-effect relationship that may exist between CP and CE practices adoption.

Keywords: circular economy, product-service systems, cleaner production, home appliance manufacturer.

1. Introduction

The concept of circular economy (CE) has been widely discussed as an effective strategy towards sustainable socio-technical systems (Geissdoerfer et al., 2017). The core of CE is the closed flow of materials and the use of raw materials and energy through multiple phases (Yuan et al., 2006). In the circular economy model, resources input and waste, emission, and energy consumption are minimized by slowing, closing, and narrowing material and energy loops (Ghisellini et al., 2016). The production is circular, i.e. raw materials and products re-enter into the environment or are reused in successive production cycles (Ruggieri et al., 2016). The CE concept has been gaining increasing attention in both academia and business practices, so that the number of publications has been increasing in the past years (Geissdoerfer et al., 2017).

Although the CE concept has become widespread, the implementation of the circular economy around the world is still restricted, especially at the micro-level (Ghisellini et al., 2016). There is still limited adoption of circular economy issues in the industry (Linder and Williander, 2015). The implementation of a circular economy program requires that companies develop new collaborative business models (Lieder and Rashid, 2016) as well as adopt different strategies to improve the circularity of its production system (Winkler, 2011). In fact, at the company production system, cleaner production (CP) is one of the main strategies to be considered as preparatory towards CE (Bilitewski, 2012; Ghisellini et al., 2016). The waste and pollution prevention which are the main important objectives of the circular economy can only be achieved by a change to cleaner production principles (Bilitewski, 2012; Ghisellini et al., 2016). Nevertheless, at the micro-level, only a few studies deal with the diffusion, adoption, and effects of cleaner production in promoting CE (Ghisellini et al., 2016).

In this sense, this paper aims to explore how cleaner production practices may contribute to circular economy implementation at the micro-level. This study investigates the cleaner production practices adopted by a manufacturing company located in Brazil that implemented a new business strategy focused on the delivery of 'functions' instead of selling products, i.e. a product-service system (PSS) business model. The shift to PSS provides the basis for a company to better contribute to CE (Witjes and Lozano, 2016), but more studies should be performed to understand the effects of CE business and consumption models implying the selling of a service (instead of a product) or its leasing, refurbishment, and remanufacturing (Ghisellini et al., 2016). Since CP practices have been considered as the most effective measure compared to other practices for CE implementation at the micro-level (Su et al., 2013), and more research should be conducted regarding CP and CE at the bottom-up (Ghisellini et al., 2016), this paper intends to contribute to the current CE empirical body of knowledge in this direction.

In fact, more extensive work in new business models as main triggers for circular economy implementation should be conducted (Lieder and Rashid, 2016). Thus, this paper provides empirical insights regarding a new business strategy and related CP practices implemented by a manufacturing company in addition to the benefits obtained from that fostered the implementation of a new circular business strategy. Moreover, the majority of studies regarding CE issues conducted so far have been performed in China (e.g. Liu and Bai, 2014; Wu et al., 2014), and more studies regarding CE principles implementation in the industry should be carried out in other emerging economies like Brazil. Emerging economies have experienced economic expansion during the last decades that consequently induced to a large consumption of natural resources (Wu et al., 2017); therefore investigations on CE principles implementation in industries in these regions are of paramount importance.

The remainder of this paper is structured as follows. Section 2 draws on circular economy literature and CE implementation at the micro-level. Section 3 describes the methods for gathering and analyzing data. Section 4 presents the circular business model under study as well as discusses the findings from the analysis of the cleaner production practices adopted by the company that fostered the implementation of the circular business. Finally, conclusions are drawn in section 5 concerning the usefulness and implications of this study, its limitations, and directions for future research.

2. Circular economy at the micro-level

In practice, circular economy approaches are implemented in three layers (Yuan et al., 2006): (i) micro, (i) meso, and (iii) macro-level. At the micro-level or individual firm level, companies act first by innovating (Ruggieri et al., 2016). At the meso-level the objective is to develop an eco-industrial network that brings benefits to regional production systems and environment (Yuan et al., 2006). The macro-level involves circular economy development in cities, provinces, or regions (Ghisellini et al., 2016).

Elia et al. (2017) proposed a four-level framework for supporting measurement of the CE paradigm adoption, which involves: (i) processes to monitor (i.e. material input, design, production/delivery, consumption, end-of-life resource management), (ii) the actions involved (i.e. circular product design and production, business models, cascade/reverse cycles skills, cross cycle and cross sector collaboration), (iii) the requirements to be measured (i.e. reducing input and use of natural resources, reducing emission levels, reducing valuable material losses, increasing share of renewable and recyclable resources, increasing the value durability of products), and (iv) the implementation levels of the CE paradigm (i.e. macro, meso, and micro). Su et al. (2013) categorized the current on-going CE practices into four areas, considering the three previously cited levels: (i) production, (ii) consumption (green purchasing and consumption), (iii) waste management (product recycle system), and (iv) other support areas (i.e. policies, law, NGOs, etc.).Within company production processes, eco-design, design for environment, and cleaner production are the main strategies to be considered when implementing CE (Bilitewski, 2012; Ghisellini et al., 2016).

CP is a strategy for addressing the generation of pollution as well as the efficient use of resources at all stages of the production process (Su et al., 2013). There are some principles involved in the implementation of CP practices (Nilsson et al., 2007; Yusup et al., 2015): (i) input substitution (use fewer hazardous materials and assure longer operating material lifetimes), (ii) good housekeeping (increase the efficiency of material and energy use in processes and reducing losses due to leakage), (iii) internal recycling (close material and energy loops for water, solvents, etc.), (iv) technological optimization/change (implementation of new technologies, improved process control, redesign of processes), and (v) product optimization (increasing product lifetime). Glavic and Lukman (2007) stated that cleaner production management strategies endeavor to: (i) increase the productivity of materials, (ii) improve energy efficiency, (iii) improve material flow management, (iv) apply preventive environmental protection approaches, (v) strive for sustainable use of natural capital, and (vi) achieve accordance with legal compliance. Yusup et al. (2015) identified in a literature review a range of CP practices and indicators, and many of those are closely related to building blocks for supporting the adoption of CE paradigm (as suggested by Elia et al., 2017), such as design strategies. Cleaner production, in fact, can be seen as one of the first and most vital steps toward the ultimate goal of circular economy in industrial sector (Li et al., 2010). Indeed, company environmental culture seems to be the main enabler for circular economy implementation (Rizos et al., 2014). Thus, the adoption of cleaner production practices as part of company culture may act as enablers for circular economy implementation.

The effectiveness of cleaner production to promote CE, however, depends on the context and also on the capacity of public authorities to stimulate an increase of the responsibility of producers towards a continuous improvement of environmental performance (Ghisellini et al., 2016). In fact, it seems that the four areas at the micro-level and respective CE practices (see Su et al., 2013) are related to each other, as in the case of CP practices adopted in the production area and laws and policies that support CE implementation from the support area. Thus, the relationship among cleaner production practices and its principles (production area), product recycle system (waste management area), and policies and laws, information platform, NGOs (support area) is also explored in this study. In fact, to obtain significant impact CP practices need to be integrated throughout the organization and should involve a range of processes, products and services for handling the use of natural resources and the reduction of waste and pollution (Yusup et al., 2015). Having presented the theoretical background, the attention is turned to the following section that describes the research procedures to collect and analyze data.

3. Research design

Since the purpose of this study was to explore CP practices adopted by the company under analysis that were the basis for CE principles implementation at the micro-level, this study presents some methodological characteristics of case-based research (see Voss et al., 2002).The first step in the research design was the development of a conceptual framework. Thus, an analysis of CE and CP literature was carried out to establish a suitable lens for the analysis. This analysis explored CP practices and indicators adopted by the company (following the CP practices indicators proposed by Yusup et al., 2015) and also according to the CP principles described in section 2 as well as the connection with CE practices from other areas at the micro-level (i.e. waste management and consumption areas, as proposed by Su et al., 2013). In addition, the cleaner production practices and indicators were analyzed from the perspective of its contribution to the requirements to be measured when transitioning towards a CE paradigm, in order to investigate how CP practices may be valuable to CE implementation as well as the synergy that exists between them.

The second step was the definition of the unit of analysis. The PSS business model that is the unit of analysis in this study was selected following the information-oriented approach recommended by Flyvbjerg (2006). In this approach, units are selected based on the expectations for the information content. As mentioned earlier, this study aimed to investigate CE implementation at industrial level in an emerging economy, since for manufacturing companies the development of new innovative business models that fit the CE context is vital (Ghisellini et al., 2016). A manufacturing company located in Brazil that has been awarded for its sustainability initiatives was identified as suitable for analysis, following the same criterion adopted by Rauter et al. (2017) for selecting the units of analysis. The company is the Latin America leader in home appliances. It has implemented a new business strategy focused on the leasing of water purifiers (a use-oriented PSS, according to Tukker's, 2004 classification). Use-oriented PSS potentially intensify the use of material products and hence could reduce the need for materials (Tukker, 2015), being a suitable PSS category for analysis in the context of CE. An exploratory single case study was adopted because it gives the opportunity for a more in-depth analysis as recommended elsewhere (Dyer and Wilkins, 1991).

To increase the construct validity, this study relied on multiple sources of evidence, including primary and secondary data sources. Data were obtained from semi and non-structured interviews with managers from different functional areas, on-site observations, and longitudinal investigation regarding the business model implementation (using internal reports). All data collected were triangulated to derive the findings. Table 1 provides an overview of the data sources and the type of information gathered.

Table 1. Overview of data sources and information gathered.

Function	Key information gathered	Information gathered by
Project manager	- Context (history of the business development process)	Onsite visit (production)
Lead product engineer	Information regarding product life cycle	document analysis (e.g. business plan report)
Marketing manager	- Context (history of business evolution) - Business model development process - Information regarding company	Onsite visit (marketing sector) document analysis (e.g. business plan report)
Service & Operations manager	- Overall service structure and process - Overall manufacturing process	Interview by phone, document analysis (e.g. business plan report)
Operations manager (End-of-life services supplier)	- Partnership structure to disassembly and recycling - Overall process of receiving, inspecting, disassembling and recycling products and components - Legal and contracts practices to ensure correct destination of materials - Incentives and profit-share structure - Supplier certification practices	Interview by phone, company website
Sustainability manager	- Company sustainability strategy - Sustainability plan and key actions - Zero waste program structure Water and energy efficiency programs - Sustainability practices adopted - Governmental and third parties relations to support the sustainability plan implemented - Suppliers certification practices	onsite visit (production), document analysis (e.g. sustainability practices report)

As a general strategy of analysis, this study firstly relied on a case description as recommended by Yin (2014). In addition, data analysis involved working on the data from the ground up (Yin, 2014) with the concepts (the propositions identified in this study) emerging by examining the data, using an inductive approach. As illustrated in Table 1, data collected using multiple sources were mapped and compared after a content analysis, and the concepts in the same phenomenon (related to the same CP principle/practice and CE requirements to be measured in the paradigm shift) were grouped. The findings were analyzed anchored to the literature, and some propositions were developed that could be subject to further testing in levering on other research designs, as suggested by Meredith (1998). The results from this research design are highlighted in the next section in addition to the business model structure.

4. Results

The first part of this section presents a description of the PSS business model and its elements (i.e. value proposition, value creation, and value capture schemes). The second part discusses the CP practices adopted by the company, their relation to CE practices from other areas based on Su et al. (2013), in addition to the requirements to be measured when transitioning towards CE paradigm.

4.1 PSS business model structure

The PSS under analysis is a use-oriented solution, focused on the delivery of 'purified water' in a leasing scheme. A small appliance (a water purifier for which fees are paid monthly) is the main product involved in the system. The services involved in the system are related to product installation and maintenance (repair, water filter replacement and cleaning). In addition, at product end-of-life, the company collects the water purifier and its components through a reverse logistics process. Long-term contractual agreements are established between customers and the company.

A range of stakeholders is part of the actors' network. Those include certified suppliers (to ensure that they meet company standards and policies for raw material use), government (and national policies such as the national policy of solid waste), a non-governmental organization - NGO (that incentives consumption patterns change through public campaigns involving plastic bottles consumption reduction), and partnerships for product end-of-life management (a specialized company that is a subsidiary of the company performs recycling and disposal of products' components). With regard to the business model elements, the value proposition of this PSS consists of the provision of safe drinking water. This is important because it has been an increase in bottled water consumption in many regions of the country, which leads to a range of environmental impacts associated with plastic bottles consumption. Value is created from the integrated collaboration of the provider, other stakeholders that are partners in the system as discussed earlier (e.g. the NGO), and consumers (which are normal citizens and other commercial establishments and companies, since the company operates in both business-to-business and business-to-consumer markets). The provider is in direct contact with consumers when performing installation and maintenance services, which allows the re-orientation of consumption patterns, knowledge transfer, and the increase of customer loyalty. The value capture is structured in a way that allows consumer access to the service provided, and it is not oriented towards product ownership.

Additionally, this new business model can be seen as a circular strategy for slowing resources loops, based on the circular business models classification proposed by Bocken et al. (2016). Through a range of initiatives (e.g. design for maintenance and reparability) product-life and its use are extended; this results in a slowdown of the flow of resources (Bocken et al., 2016). The business model implementation required a mindset change in the company, from businesses focused on manufacturing and selling of products towards the provision of an offering focused on the delivery of 'functions'. A range of practices adopted by the company allowed this transition and the achievement of environmental benefits, especially the CP practices, which are discussed in the following section.

4.2 CP practices and CE issues adopted by the company

As mentioned earlier, the company implemented a range of CP practices and principles that allowed the development and implementation of the new circular business model. The main CP practices identified and correspondent indicators following Yusup et al. (2015) are presented in Table 2 as well as their contributions to the achievement of the requirements to be measured for CE implementation as proposed by Elia et al. (2017).

Table 2. Cleaner production practices adopted by the company and contribution to CE.

CP practice performance indicator	CE requirements contribution
Increase the durability of the products	Increasing the value durability of products
Implementation of waste minimization programs	Reducing valuable materials losses
Optimization the recyclability in product design	Increasing the value durability of products
Integration in environmental issues in process and innovation	Increasing the value durability of products
Optimization of environmental issues in supplier selection	Increasing share of renewable and recyclable resources
Reduction of the use of raw materials and resources	Reducing input and use of natural resources
Simplification of the product installation process	Increasing the value durability of products
Efficient use of chemicals in manufacturing processes	Reducing emissions levels, reducing valuable materials losses
Integration of environmental issues in the logistical design	Reducing valuable materials losses
Reduction in the use of natural resources in manufacturing processes	Reducing input and use of natural resources
Evaluation of the replacement of materials with non-toxic and non-polluting products	Reducing emission levels, increasing share of renewable and recyclable resources
Improving in the recyclability in operational activities	Increasing the value durability of products, reducing valuable materials losses
Evaluation of the possibility of changing the material composition of products	Reducing input and use of natural resources
Share information about recycling programs and standard practice with stakeholders	Reducing valuable materials losses, reducing input and use of natural resources
Optimization of recycling, remanufacturing and reuse in product design	Increasing the value durability of products
Use energy-saving equipment	Reducing input and use of natural resources, reducing emissions level

Concerning the CP principle of product optimization (Nilsson et al., 2007), the interviews revealed that new capabilities were developed by the R&D organizational area, and new design strategies for slowing resources loops aligned with CE principles (Bocken et al., 2016) were implemented such as design for ease maintenance and repair, design for reliability, and design for durability in order to develop products with extended lifetime. The products have been designed in alignment with the consumer profile (i.e. business-to-business or business-to-consumer market), in order to increase its durability according to use patterns of consumers. Other identified CP practices adopted were optimization the recyclability in product design, improvement of recyclability in operational activities, simplification of the product installation process. Those were interpreted as valuable to increase the value durability of the products. Thus, the first proposition is:

- CP practices for product optimization are valuable to CE implementation regarding circular product design strategies as well as to increase the value durability of products.

With regard to the CP principle of input substitution, the company developed a practice focused on the use of materials that minimize total life cycle impacts. The company introduced a critical materials management program and developed new processes and capabilities that allow tracking, collection, and assessment of every chemical composition of its products. This program enables the company to manage material according to the regulation and to understand material risk. A range of alternative substances has been used in order to minimize the environmental impacts and increase the energy efficiency of products and processes. One of the company's goals is by 2020 to achieve 90% full material transparency on all products. The materials consumption is managed internally, and audits are performed periodically following the principles of ISO 9000, ISO 14001, and OHSAS 18001. In addition, the company also works close with suppliers to establish transparency regarding its process and materials used, in order to eliminate hazardous components in all suppliers' products and processes. The suppliers are incentivized to adopted green practices by the development of a supplier excellence program that gives incentives and sustainability awards for those with the best sustainability practices. This was noticed as valuable to overcome a challenge for CE implementation regarding the lack of incentives for older industries to 'green' their operations (Geng et al., 2009).

Regarding water consumption, the company has been treating and purifying water through wastewater treatment stations for processes consumption as well as capturing rainwater. The water intensity in the plant was decreased by more than 70% during the last ten years, through water reuse, processes improvements and refurbishment, innovation and new technology implementation and training. In addition, effluents from its operations are treated before discarding them in the sewage networks, ensuring compliance with environmental legislation and preventing pollution. Thus, CP practices such as evaluation of the possibility of changing the material composition of products, reduction of the use of raw materials and resources, reduction in the use of natural resources in manufacturing processes, share information about recycling programs and standard practice with stakeholders were identified as important to reduce input and use of natural resources in the paradigm shift towards CE. Moreover, the evaluation of the replacement of materials with non-toxic and non-polluting products and optimization of environmental issues regarding the suppliers' selection allow the use of more sustainable sourcing, increasing the share of renewable and recyclable resources. The second proposition, in this sense, is:

- The CP principle of input substitution is valuable to reduce input and use of natural resources and to increase the share of renewable and recyclable resources.

Regarding the principles of increasing the efficiency of material and energy use in processes and reduce losses due to leakage (good housekeeping), and internal recycling, the company developed a zero waste to landfill program targeting zero waste from manufacturing. The company has been committed to reducing waste generation in its production activities, and reusing, and recovering materials are widely practiced throughout the plant. What cannot be reused is recycled and when that is not possible, the company tries to dispose it with minimal environmental impact (waste-to-energy conversion or treatment). To keep track of the performance of this process, a specific indicator called 'total waste' was set up (kg/unit), which is the total waste material generated to produce one appliance, including waste material from three main areas: (i) technological: material not used during the transformation of raw material into product, (ii) scrap: material wasted due to damaged or not right first time handling and scraps from processes, and (iii) packaging: material used to protect the raw material during the transportation and storage. Improvements in the recyclability in the operational activities were achieved with the zero waste program. In addition, the implementation of a closed loop model to recover and recycle products through reverse flows at the end of life allows preventing waste production and decrease material losses. Thus, the third proposition is:

- Good housekeeping and internal recycling may allow reducing valuable materials losses.

Concerning the CP principle of technological optimization, the company implemented an energy efficiency program that aimed to improve the efficiency of its process through projects focused on the development of new technologies and some practices (e.g. equipment parts replacement). The products are also developed in other to consume less energy during the use phase. In addition, the facility efficiency was improved by applying technology improvements and renewable use (e.g. LEED). The fourth proposition is:

- Technological optimization can contribute to reduce emissions level.

Moreover, the CP practices adopted in the production area are connected with the waste management area. Additionally, some CP practices regarding the critical materials management program and suppliers management are connected with consumption area, which involves green purchase and consumption. Furthermore, CP practices implementation that is aligned with the paradigm shift towards CE is also connected to the support area (policies and laws) from a top-down perspective. The waste management program was implemented in order to be aligned with the Brazilian policy of solid waste. The policy was an enabler for CP implementation which was valuable to CE principles introduction regarding waste reduction.

In addition, the waste management encouraged the development of another company that plays a role as a scavenger (i.e. that feeds the waste resource of the company and other stakeholders in the economic system). This new company is a subsidiary that performs the complete recovery of the materials, which allows its valorization, generating new materials for the production process, and also for other industries. The creation of this new business unit also allows the reverse logistics of other products and components of the traditional business model (i.e. the other business focused on the sale of other home appliances manufactured by the company). All recyclers that are partners in the business are certified, and the company ensures that all waste is recovered. As a consequence, the company has the complete control of the full product life cycle, which is important for CE implementation at the industry level (Lieder and Rashid, 2016). Thus, the fifth and last proposition is:

- CP practices at the production area enable CE practices implementation at the micro-level and are connected to other CE areas (i.e. waste management, and support).

It could be noticed that all CP practices and principles implemented by the company were enablers to CE issues implementation regarding the new business strategy. After presenting the findings, next section outlines the main concluding remarks of this study.

5. Conclusion

This paper has addressed cleaner production practices and principles and CE implementation at the micro-level. The research was conducted in response to current limited empirical evidence regarding the specific issues surrounding circular economy principles adoption in manufacturing firms, especially those related to CP, which has been highlighted as the first step when moving to CE business strategies in the industry.

Five propositions were developed from the analysis of the CP practices implemented by the investigated company and its new CE business strategy. Those stated that connections between CP practices and principles and CE implementation at the micro-level exist, and CP practices foster the implementation of CE principles in the industry. The first proposition is that CP practices for product optimization are valuable to CE implementation regarding circular product design strategies and to increase the value durability of products. The second proposition states that CP principle of input substitution is valuable to reduce input and use of natural resources as well as to increase the share of renewable and recyclable resources. The third proposition asserts that increase in the efficiency of material and energy use in processes and internal recycling may allow reducing valuable materials losses. The fourth proposition affirms that technological optimization can contribute to reduce emissions level. Finally, the last proposition states that CP practices at the production area enable CE practices implementation at the micro-level and are connected to other CE areas (i.e. waste management, consumption, and support). Thus, the developed theoretical propositions can be explored by further studies. At the practical level, this study provides insights to practitioners regarding CP practices that may be valuable to support CE implementation.

The limitations of this study primarily revolve around the fact that a single unit of analysis was adopted. Nevertheless, circular business implementation in manufacturing companies, especially in the context of other emerging economies and developing countries are still underdeveloped, so it requires further exploration. Further studies may focus on exploring the propositions developed in this study in other units of analysis and manufacturing contexts in addition to investigate the cause-effect relationship that may exist between CP and CE practices adoption at the micro-level.

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